Concept of Field Storage of Ammunition and Explosives in 20' Standard Container

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ABSTRACT

This paper presents a summary of the work carried out by DEMEX Consulting Engineers A/S for the Army Material Command and the Army Explosive Safety Chief Inspector concerning field storage of ammunition and explosives especially in the area of the former Yugoslavia where Danish UN-forces have been deployed for the last two years.

Due to logistic matters and the use of air-conditioning equipment in the storage rooms, the Army uses standard 20' containers. The work has been concentrated to find a practicable concept where the safety aspects are not jeopardized and still according to the AC258 manual.

Both internal and external barricades have been studied including some calculation of the disintegration of the ammunition container. Simulations of the blast propagation have been carried out by use of the HEXDAM-B code.

BACKGROUND

The Danish UN-forces in the former Yugoslavia are to a large extent quartered in field camps. These camps are based on a wide use of standard containers, because they offer large flexibility and mobility. Also ammunition and explosives are stored in containers, and due to the limited area available, these containers are placed comparatively close to living quarters.

The Danish Army Explosive Safety Chief Inspector therefore initated the present study in order to evaluate the container storage concept and to ensure optimum protection of troops against blast waves and fragments.

The study has been carried out taking the mass-detonation of 500 kg TNT as the threat. Although more explosives are sometimes stored in a container, 500 kg is a realistic upper limit.

The effect of the blast wave is the main subject of the study, but fragments are also considered.

The study ends up with recommendations for the placement of ammunition containers and sandbag walls.

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INTRODUCTION

The goal of the first part of the study was to estimate the resistance and protection obtained by the container itself and to investigate the possiblitity of controlling the direction of fragments and the blast wave.

Subsequently the use of sandbag walls to reduce and direct the effects of the blast wave and fragments is treated, finally the potentail for reduction of safety distances is evaluated.

The behaviour of the elements involved in the explosion (gases, fragments, sandbags, container) is extremely complex and can only be described in detail for a few simple theoretical cases. For practical calculations approximations and simplifying assumptions are - as in the present study - necessary. The calculated figures are therefore to be regarded as rough but qualified estimates.

Terminology

The container considered is a 20' container as specified by IS0 668 with an insulating kit added. In figure 1 a schematic view of the container with the applied terminology, is shown.

Figure 1 Container with DS/ISO 668 dimensions and applied terminology.

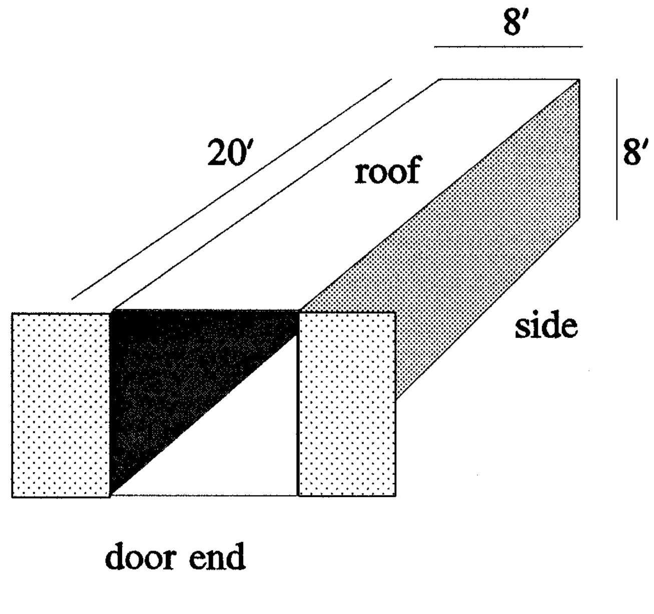

Figure 1 Container with DS/ISO 668 dimensions and applied terminology.

LOCAL BLAST EFFECTS BY DETONATION IN CONTAINER

In this chapter the local blast effect on the container itself will be considered.

General Assessment of Damage By Explosion in Container

In order to assess the typical damage caused by an explosion in a container, an evaluation of the strength of the container was carried out.

By considering the least exposed part of the container, that is the backwall which is assumed to be farthest from the explosion, the amount of TNT required to disintegrate the container totally is about 15 kg. This amount was calculated considering the primary reflected pressure assuming that the primary blast wave alone disintegrates the container. 15 kg TNT will generate a reflected pressure of 1,2 MPa and an impulse of 1 kPas, which will cause a plastic deformation of the container wall.

For explosions of amounts somewhat smaller than the 15 kg, the container can be considered to have an effect on the direction of propagation of the blast wave, but for somewhat larger amounts of explosives the effect of the confinement of the container can be neglected and the explosion can be regarded as an explosion in open air.

Since a detonation of a limited amount of the explosives in a container is a likely situation it is important where the explosives are stored in the container. If the explosives are stored close to the door-end, the door is likely to blow out, and thus there is a fair chance of directing the blast wave and fragments out through the door.

CONTAINER COMBINED WITH SANDBAG WALLS

In the previous section it was demonstrated that an ammunition container in itself only provides protection of the surroundings for detonations of limited amounts of explosives.

In this section suggestions for and evaluation of the use of sandbag walls against the blast wave from the explosion are presented.

Blast Wave Effects on Sandbag Wall

In order to estimate the effect of using sandbag walls, a number of calculations of the impact of the blast wave on given sandbag walls have been carried out.

In table 1, the acceleration, velocity and the displacement of the sandbag wall after experiencing blast wave from the explosion are listed. The calculated displacement assumes a distance of 5 m to the center of explosion of 500 kg equivalent TNT. Reflections from floor, roof and walls are included by multiplying the mass of the charge by a factor 1.8 [2]. The reflected pressure peak P_r is thus calculated using a charge of 900 kg TNT. Furthermore, in order to take into account multiple reflections, P_r is multiplied by a factor 1.75 [5]. The duration of the pressure pulse has been calculated as $t = 2i_r/P_r$.

Distance m	P_r Mpa	P_r' Mpa	i_r Pa s	t ms	acceleration m/s^2	displacement mm	velocity m/s
1	400	700	$1{,}9\ 10^5$	0,95	350.000	158	330
2	140	245	$5{,}4\ 10^4$	0,77	123.000	36	95
5	33	58	$1{,}2\ 10^4$	0,70	29.000	7	20
10	3,7	6,5	$5{,}4\ 10^3$	2,9	3250	14	9
20	0,68	1,2	$1.2\ 10^3$	3,6	600	4	2

Table 1. Effect of 500 kg TNT blastwave on 4' sandbag wall (2.000 kg/m^2) at different distances.

From the table it is seen that the displacement of a sandbag wall during the pressure pulse is not important, although it is accelerated to quite a high velocity.

In order to evaluate how effective the sandbag wall is as protection against the blast wave, it is important to have an estimete of how much the sandbag wall moves, before the container has been ventilated, or in other words, wether it is likely that the pressure will be ventilated by the door and not just in all directions.

In [6] experiments in confined spaces with almost identical dimension and one end open have are reported. The pressure in the end opposite the open end was recorded. After the primary pressure wave a series of reflected waves of decreasing amplitude are observed. The strongest of the reflected waves is typically half as strong as the primary wave.

After about 50 ms the pressure has reached that of the environment. Even though only 2,5 kg of TNT has been used in [6], it is reasonable to assume that the pressure in the ammunitioncontainer will return to the pressure of the environment in approximately the same period of time. The sandbag wall will move during the 50 ms, the question is how far and thereby how much of the blast wave that will pass.

Distance	Displacement of sandbag wall after 50 ms			
m	2000 kg/m2	1000 kg/m^2	5000 kg/m^2	10000 kg/m^2
1	16 m	33 m	6,6 m	3,3 m
2	5 m	9 m	1,8 m	0,9 m
5	1 m	2 m	0,4 m	0,2 m

Table 2 Displacement of sandbag walls of different areal weights at different distances from the explosion. 500 kg/m2 corresponds to a 1' thick sandbag wall.

In table 2 is listed the displacement of the sandbag wall after 50 ms, assuming that the wall is instantly accelerated to the velocity calculated in table 1 and does not change velocity. Other areal weights of the wall are also included in the table. In practice the walls will not move as rigid walls as assumed here, they will turn over; the purpose of the calculation is is estimate to what extent the sandbag wall can reduce the effects of the explosion.

Use of Sandbag Walls inside the Container

As it appears from table 1, the effect of the explosion on a sandbag wall very close to the explosion is extremely powerful, and it is not likely that the relatively thin wall that could be fitted into the container would provide protection of importance.

When also operational requirements, such as easy access to the ammunition and mobility of the container, are regarded, sandbags inside the container do not seem to be an effective solution.

Use of Sandbag Walls around the Container

Based on the figures calculated in table 1 and 2, the following suggestion for protection against the shockwave in the threatened directions:

Sandbag walls are placed in all threatened directions, that is on all sides of the container except for the door, which is assumed to point in a direction where there are no threatened object. Sandbags are also placed over the roof of the container.

It is suggested to use 4' thick sand bag walls on the sides on 2' of sandbags on the roof. The thickness has been chosen as a compromise between good protection and practicability of the solution. By choosing larger thickness higher safety can be attained or vice versa.

The concept forms a kind of 'garage' for the container. The outline of such a garage is shown in figure 2.

Figure 2. 'Garage' of sandbags for ammunition container. Front view. Not to scale.

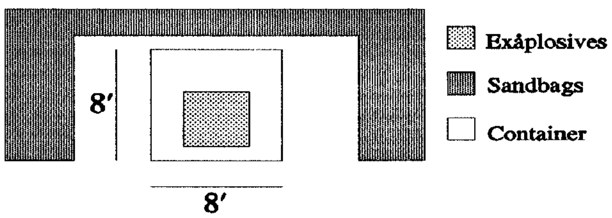

Figure 2 'Garage' of sandbags for ammunition container. Front view. Not to scale.

Figure 3. 'Garage' of sandbags for ammunition container. Top view. Not to scale.

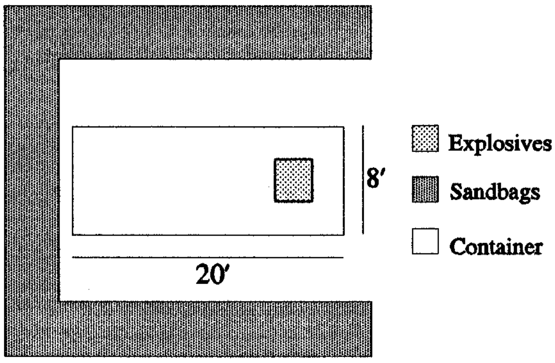

Figure 3 'Garage' of sandbags for ammunition container. Top view. Not to scale.

More containers can be placed together in a 'garagesystem' so that two containers share a side-wall. See figure 4. Sandbag walls between containers are kept to avoid damage to adjacent containers from fragments or fire.

Figure 4. 'Garage-system' for 4 ammunition container. Front view. Not to scale.

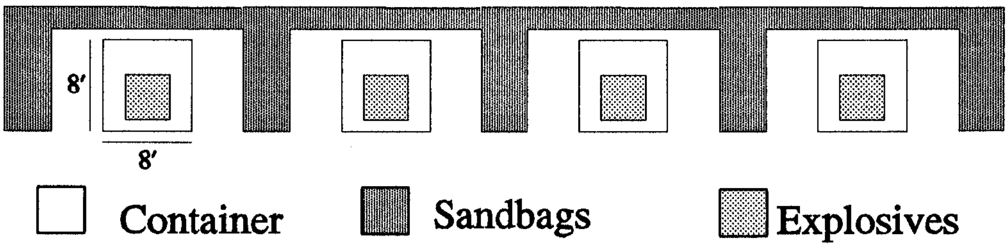

Figure 4. 'Garage-system' for 4 ammunition container. Front view. Not to scale.

Evaluation of Protection Level

With the chosen thickness of the sandbag wall, a considerable reduction just behind the wall is expected. In addition to the reduction of the blast wave, fragments and ejected ammunition will be avoided to a large extent. This has been confirmed by experiment in [7].

From table 1 it is seen that the wall practically will not move during the primary pressure puls even when the wall is very close to the explosion. Thereby it is clear that the primary pulse will be stopped and the peak pressure of the blast wave at least be halved.

The distance of the sandbag wall from the explosion is decisive for how many of the reflected waves that will pass the wall. From table 2 a wall at 1 m is seen to move so much that only elimination of the primary pressure wave can be expected. At a distance of 5 m the displacement of the wall is so limited that it is reasonable to assume that also the main part of the reflected waves will be eliminated.

The exact reduction of the blast wave is difficult to estimate. Still, an effect similar to that of an earth covered magazine can be assumed.

As regards ejection of fragments, these will constitute a threath in an angle of 120 degrees around the door. These fragments can to a large extent be avoided by placing a thin sandbag wall a few meters in front of the door. In an angle of 120 degrees opposite the door end good protection against fragments and the blast wave is obtained.

In the 60 degrees angles in between a good protection against fragments and a reduced peak pressure can be expected. See also figure 5.

Figure 5. Protection level for garage-concept.

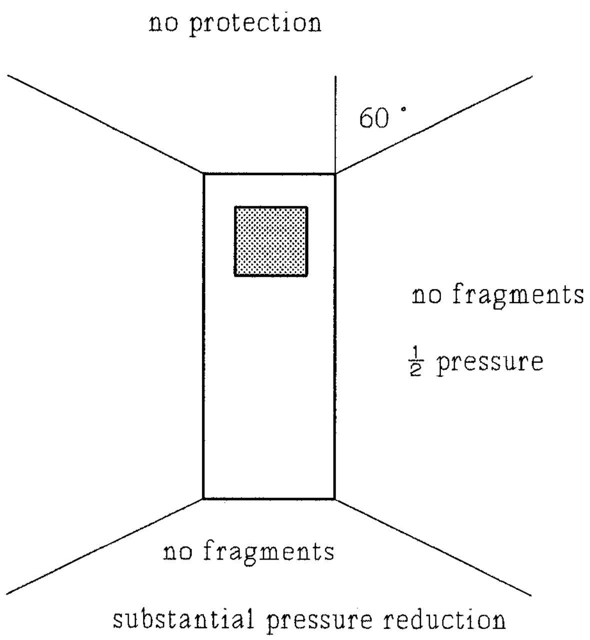

Figure 5 Protection level for garage-concept.

SAFETY DISTANCES

Table 3 lists safety distances according to the Danish regulations [12].

Protection Level [Q in kg, dist. in m]	Overpressure [kPa (psi)]	Dist. for 250 kg [m]	Dist. for 500 kg [m]	Dist. for 1.000 kg [m]	Dist. for 2.000 kg [m]	Damage	Category
22,2 $Q^{1/3}$	5 (0,7)	140	175	220	280	slight	inhabited areas
14,8 $Q^{1/3}$	10 (1,4)	90	115	150	185	slight	roads, railways
9,6 $Q^{1/3}$	16 (2,3)	60	75	100	120	moderate	training ground
8,0 $Q^{1/3}$	21 (3,0)	50	60	80	100	severe	Amm. workshop, tr-ansit build.
7,2 $Q^{1/3}$	24 (3,4)	45	55	70	90	severe	Amm. preparation, guards
3,6 $Q^{1/3}$	70 (10)	25	30	35	45	total high mortality	Operational considerations

Table 3 Protection level against overpressure [12].

The required safety distance for an unprotected container is thus 175 m for a 500 kg charge. If the pressure is halved the distance can be reduced to 115 m.

As mentioned earlier, a considerable improvement of the protection level can be obtained by placing a sandbag wall right in front of the threatened object.

The software HEXDAM-B has been used to demonstrate the effect of sandbag walls in front of the threatened objects. The software calculates the propagation of the pressure wave and takes into account the shieldning effects. Figure 6 shows the initial configuration. The 500 kg TNT charge is placed at (0,0) 1 m above ground. At given distances, 20' containers have been placed. Figure 7 shows the overpressure generated (in psi) when no sandbags are used. In figure 8 is shown the result when a 10' high sandbag wall is placed 4' in front of the threathened containers.

Figure 6. Initial configuration

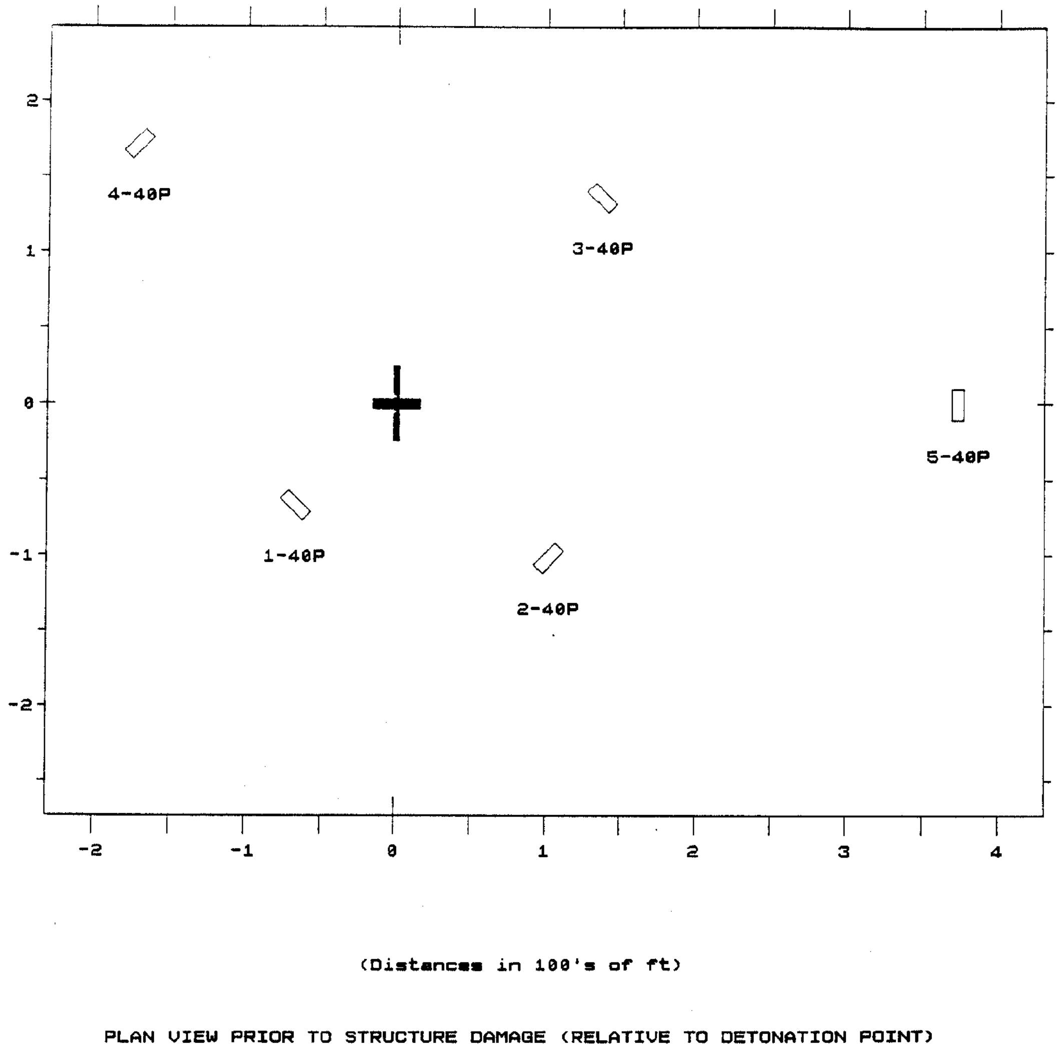

Figure 6 Initial configuration.

Figure 7. Overpressure generated (in psi) when no sandbags are used

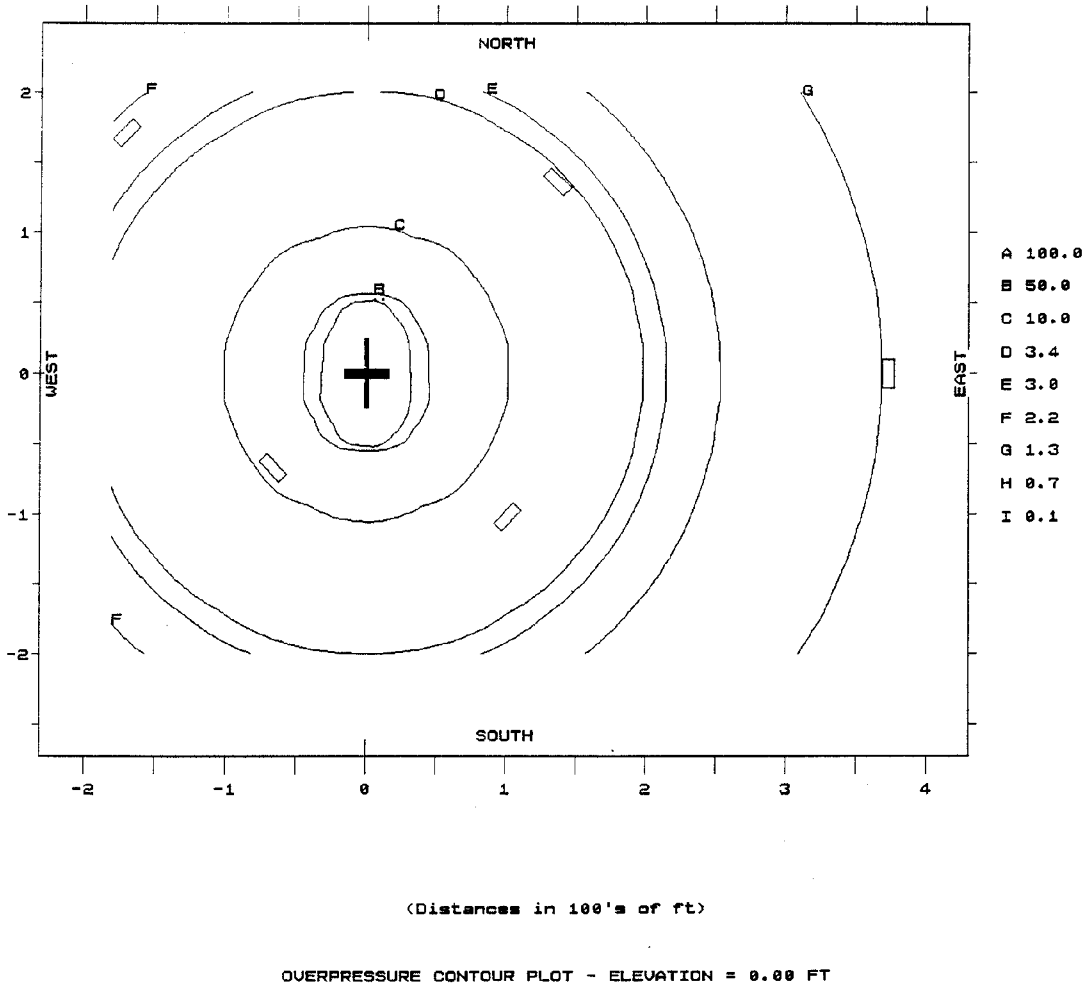

Figure 7 Overpressure generated (in psi) when no sandbags are used.

Figure 8. Overpressure generated (in psi) when sandbags are used

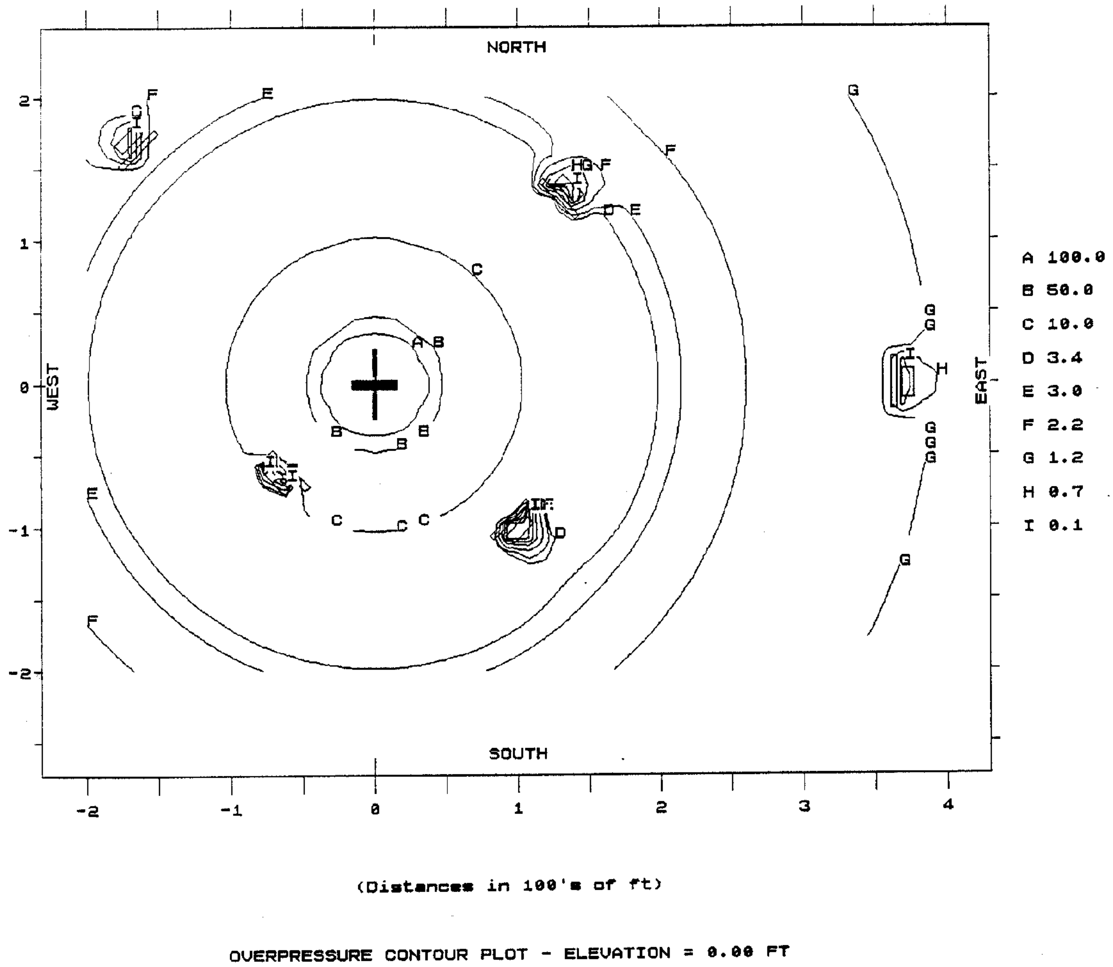

Figure 8 Overpressure generated (in psi) when sandbags are used.

CONCLUSION

From the study it can be concluded:

- By detonation of more than 25 kg equivalent TNT, the container provides no protec tion of the surroundings in itself. The functions of the container are solely transport, storage and air-conditioning.

- Protective measures inside the container are not considered feasible.

- By use of a socalled 'garage'-construction, where the container is surrounded by sandbag on three sides and the roof, the effects of the explosion can be directed and provide considerable reduction of safety distances on the three protected sides of the container.

- By use of sandbag walls immediately in front of threatened objects, an substantiallly reduction of safety distances is also achieved.

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